AGROFORESTRY FOR FOOD IN THE U.S. CORN BELT: KEY ASPECTS OF TREE CROP IMPROVEMENT TO ENABLE NOVEL SYSTEMS

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Abstract

Numerous tree crop species are available for integration into agroforestry. To best guide this integration, a systematic process is needed to understand the transferability of improved tree crop selections beyond the specific environments in which they were breed and tested. In the U.S., the integration of tree crops will largely be constrained to the marginal land-types of maize. Thus, fundamental to understanding the prospective environmental transferability of tree crops is discerning the overlap between their suitable land-types and those that are marginal (to maize). Defining of this “overlap” can the guide integration of existing breeding selections and more importantly define the target environments for continued variety improvement.

Keywords: tree crops; breeding; decentralized; target environment

Introduction

The benefits of agroforestry’s regulatory services are well characterized in the Midwest U.S. Select systems can even improve farm-level profitability when strategically integrated into the agricultural landscape (Brandes et al. 2016; Brandes et al. 2017; Wolz 2018), bringing pragmatism to the strategic diversification within U.S. Corn Belt. Nevertheless, adoption of agroforestry systems continues to be relatively minimal throughout this region.

A growing body of literature suggests a path to increase the adoption potential of U.S. agroforestry systems lies in the integration of food producing tree crops (henceforth referred to as tree crops) (Jose 2009; Lovell et al. 2017; Mattia et al. 2016; Mattia 2017; Molnar et al. 2013; Mori et al. 2017; Rhodes et al. 2016; Wolz et al. 2017; Wolz and DeLucia 2018). Such systems, described as Multifunctional Woody Polycultures (Lovell et al. 2017), provide a unique opportunity to integrate new food production capacity into the Corn Belt simultaneous to the addition of regulatory services (Lovell et al. 2017; Wolz et al. 2017). While these agroforestry systems are studied and considered for adoption, the extent is limited by the availability of improved and adapted tree cop germplasm.

Numerous tree crop species are available for integration into agroforestry systems (Molnar et al. 2013); however, they are often underutilized species and have varying degrees of assembled genetic resources. Additionally, the development of these tree crops will in many cases be constrained to the marginal land-types of maize. Presently, the discrete classification of these marginal land-types as they relate to the productive potential of the tree crops of interest is not known. These realities present a gap in which to focus agroforestry development for the U.S. Corn Belt.

Fortunately, select tree crops of interest are rather amendable to schematic breeding and have wild relatives endemic to the range of the U.S. Corn Belt. Here, we present key aspects to systematically exploit these tree crops and their wild relatives to adapted cultivated germplasm to targeted marginal environments of the U.S. Corn Belt and as a result enable the integration of new agroforestry systems.

Key aspects of tree crop improvement

Tree crop wild relatives (TWRs) have a large role to play in the extent to which agroforestry development integrates into the U.S. Corn Belt. Three key roles of tree crop wild relatives that are essential to recognize are:

i. The suitable habitats of tree crop wild relatives can help inform the marginal lands that agroforestry research targets development.

ii. Tree crops wild relatives are often a rich source of novel diversity that is exploitable (Migicovsky and Myles 2017; Miller and Gross, 2011) and can create new opportunity for agroforestry (Molnar et al. 2013).

iii. Steps i. and ii. allow breeders to decentralized selection to the identified target environments; the fundamental step towards expanding agroforestry's potential integration.

Defining target environments for tree crop adaptation

In the Central U.S., target environments for tree crop adaptation are primarily constrained to environments where the maize-soybean rotation is low-yielding. This constraint muddies expectations regarding the respective availability and scale of environments that are suited to tree crops. Additionally, the abiotic characteristics of low-yielding land can vary significantly from one farm to another, which results in many discrete target environments. Adaptability traits to these target environments can be leveraged from tree crop wild relatives and introgressed into cultivated selections, but executing this scheme requires a framework to define and prioritize target environments. Here, we conceptually define the target environments and lay forth a systematic framework to identify the characteristics of these environments concerning the tree crop of interest.

Target environments will be structured base upon deviations from the soil and rainfall parameters that are suitable to the cultivated selections. Therefore, it is first necessary to define discrete classes of suitability. The classes are as follows, as presented in Kidd et al. (2015):

i. Well suited – no limitation to productivity

ii. Suited – minor limitation to productivity

iii. Marginally suited – moderate limitations to productivity

iv. Unsuited – serve limitations to productivity

Limitations reflect known constraints in soil, rainfall, or topography that influence productivity of cultivated selections of the tree crop. These parameters are contextualized using hazelnut as example in Table 1 (adapted from Kidd et al. 2015).

Table 1: Suitability parameters of cultivated hazelnut (adapted from Kidd et al. 2015).

Suitability class	Soil depth (cm)	pH (0-15cm)	EC (ds/m) (0-15cm)	Clay % (0-15 cm)	Soil drainage class	Stone % (>20 cm)	Rainfall, mean August (mm)
Well suited	>50	>6.5	<0.15	30-50	Well to moderate	<10	<80
Suited	40-50	5.5-6.5	<0.15	30-50	Imperfect	10-20	<50
Marginally suited	30-40	6.5-7.1	<0.15	30-50	Imperfect	10-20	<50
Unsuited	<30	<5.5 or >7.1	<0.15	>50 or <10	Poor to very poor	>20	>50

Detailed characterization of the target environment is, of course, a species-specific task, and it will largely be dependent upon geospatial mapping to identify overlap between the conditions suitable to the tree crop of interest (and its relevant wild relatives) that also render maize low-yielding. As mapping distinguishes prospective target environments, their respective sizes and amenability to germplasm improvement can guide the priority in which they are targeted. While conceptually straightforward, discrete characterization of the target environments will expose the most pertinent abiotic limitations to tree crop adaptation as well as the corresponding TWR adaptive traits need for development pipelines. Specifically, the output of geospatial mapping would inform: i) target environments presently well suited or suited for initial testing of breeding selections ii) and exploitation of corresponding TWR accessions to improve the adaptability of cultivated selections to respective target environments.

Conclusion

Diversifying the availability of adapted and improved tree crops provides Midwest U.S. farmers with more options for adopting agroforestry. However, the broad integration of tree crops will be most successful only if the tree crops' productivity is maintained on unproductive row-crop acreage. This talk lays forth a systematic framework to accomplish tree crop adaption and improvement in this regard and provides examples using hazelnut.

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